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GENERAL SCIENCE.—*Psychophysics as the key to the mysteries of physics and of metaphysics.*[1] LEONARD THOMPSON TROLAND, Harvard University.

I. THE PRESENT PHILOSOPHICAL STATUS OF PHYSICAL SCIENCE

Physical science begins with the naïve man's division of his everyday experience into *external* and *internal* portions. One of these portions comprises for the primitive intellect an external *world* while the other part makes up the man's own personal feelings. The line of demarcation between these two segments of experience seems at first sight to be quite distinct. There are, however, obvious affiliations between components of the two subdivisions of experience. One's own body, as visually or tactually perceived, is a portion of his external experience, but its posture and its movements are normally correlated with internal feelings, this correlation giving rise to the idea of will, or the control of one's own externally perceived body and its relations to the external world, by changes in the internal feelings. The notion of consciousness in other men is at first simply a belief in the existence of further systems of internal feelings which are correlated with the behavior of other externally perceived organisms which resemble in general form, if not in central position, the organism of the given individual.

For the primitive intellect, standing at the threshold of scientific inquiry, physics would undoubtedly be the science of the external world thus defined, while psychology would be the science of the internal system of feelings or of any other similar system of feelings which might be inferred to exist beyond the experience of the given observer. However, as science advances on its quest for knowledge the province of physics in relation to experience constantly narrows, while that of psychology undergoes a compensatory expansion. The naïve physicist looks upon his external experience as being independent of himself because, with the single exception of his own externally

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perceived organism, it does not immediately follow the dictates of his feelings. This demand, that physics should conceive a universe which is independent for its properties of any particular observer, has been implicitly observed by all physical thinkers down to very recent times. Its actual consequences have been precisely that narrowing of the domain of physics within experience to which I have adverted. The end result, as it appears in the Einstein theory of relativity, seems to have been the complete elimination of the direct data of experience from the domain of physics and consequently a reduction to an irreconcilable contradiction, of the respective demands that physics should be *strictly empirical* and yet at the same time should describe a universe which is *independent of any given experience.*

The first step in the gradual reduction of the physicist's domain within experience involved the accumulation of a long list of so-called *secondary qualities* which constitute what the psychologists now regard as external *sensations.* The qualities which headed this list were naturally those which bore the greatest similarity to the internal feelings which were the initial subject matter of mental science. Under critical examination we find that the external and internal qualities are not so very different after all so that they can be arranged into a nearly continuous series in order of their projicient character. Chemistry at an early date eliminated qualities of taste and smell from its catalog of supposedly actual properties of specific material substances, regarding the gustatory and olfactory characteristics as being merely psychological tests indicative of certain molecular forms of constitution. The theory of heat soon became inconsistent with the existence of two qualitatively opposed thermal elements corresponding with our experiences of cold and of heat, respectively, so that these two distinctive constituents of immediate experience had also to be banished from the domain of physics. The earlier physicists regarded color as an objective property of light or of bodies, but with Newton we find color being treated as a sensation, or as something produced by the organism under the influence of light, which latter in itself is not colored, being not even white or black. With the introduction of the wave theory of radiation, color necessarily and permanently lost its position as a subject matter of physical science, and was relegated to psychology. The wave theory of sound did a similar thing for auditory qualities of pitch and noise. In Helmholtz's two great works dealing, respectively, with physiological optics and

physiological acoustics we find the most eminent physicist of the nineteenth century explicitly treating both color and tone as physiological or psychological entities.

Up to the advent of the theory of relativity (in the twentieth century) it appeared that this process of eliminating the qualitative constituents of external experience from the domain of physics still left within this latter domain three distinctive factors: those of space, mass, and time. The physicist of this period was painstakingly construing all of his data and theories in terms of the centimeter, the gram and the second. These were regarded as being the ultimate physical dimensions, out of which all other physical conceptions must be synthesized. It is true that the developing theory of electricity apparently demanded two other dimensions: those of dielectric capacity and of magnetic permeability, respectively, but these latter conceptions attached more to the *hypotheses* of physics than to its actual measurements. Now from the point of view of psychology or the analysis of immediate experience, space, mass, and time are radically different categories. Only *mass* can properly be regarded as being interpretable as a *quality* of experience. As such it is clearly identifiable with sensations or experiences derived from the so-called *proprioceptors*, or the sense organs of the motor mechanisms of the body, including not only the muscles but the tendons and the joints. It is probable, however, that this feeling of *bodily effort* is more immediately associated with the conception of force than of mass, so that it may be necessary to regard mass as being derived from it by combination with the concept of acceleration, which is a special relationship between spatial and temporal magnitudes. It is of interest that the kinaesthetic quality, which is one of the cardinal constituents of internal experience, should turn out to be about the last directly qualitative experimental factor to remain in the system of physical thinking.

Space, from the psychological point of view, may in some cases be regarded as forming a distinctive qualitative constituent of consciousness. There are sensations for example which possess a spatial or extensive quality while others are lacking in this attribute. In the majority of instances however we are forced to regard space in experience as representing a *form of combination* of elementary qualities rather than as comprising such a quality in itself. In this sense space is a category of *structure* rather than of substance. Visually perceived

surfaces for instance are to be regarded as concatenations of color elements, which latter in themselves cannot constitute any surface, however small. On the other hand, the impression of empty space separating the eye from the color surface must be regarded as involving a distinctive visual element of depth, which cannot be identified with color; these depth elements, however, are in themselves non-structural and must be arranged into a structure in order to present an experience of distance or of volume. Now, it is clearly the structural rather than the substantial aspect of spacial experience which physics considers. The physicist arranges his units of mass in imagination into a three-dimensional pattern which is structurally similar to the arrangements of qualities, such as color or touch sensations which he finds in immediate experience. The similarity however, is not complete, since none of the spaces, visual, tactual or auditory, of our consciousness are strictly Euclidean in character. They are all more or less anisotropic or possessed of different properties in different directions, and they are obviously very imperfect and incomplete in relation to the totality of the universe.

The category of *time*, again, is psychologically quite distinct in nature from those of mass or of space. Time is not qualitative, neither is it structural, for it concerns quite another aspect of experience, namely its liability to *change*. The idea of time is inflexibly bound up with the fact that experience is a process or a flux. This flux consists in the replacement of one form of consciousness by a different one. Within consciousness or experience in concrete form such processes involve transmutations not only of structures but of qualities. Physics, however, having eliminated the latter, must confine itself to changes in spacial structure, or to motion. Time, for physics, thus becomes a conception of the relation between motion and the thing which moves; in any single instance it is measured by the ratio of a distance to a velocity, a definition which must be supplemented in situations involving a multiplicity of concurrent motions, by a definition of *simultaneity*. Time, both from a psychological and from a physical or mathematical point of view, is a complex conception based upon two ultimate facts: those of change and of the interdependency of concurrent changes.

Although the relations between the space, mass and time concepts of physics and the corresponding conceptions relating to immediate experience are clearly somewhat involved, it was nevertheless possible

for a philosophically uncritical physicist prior to the advent of relativity theory to regard his subject matter as an actual abstraction from immediate experience. I say "philosophically uncritical" because even before the advent of the Einsteinian theory a very close scrutiny of the relations obtaining between physical ideas and the actual data of consciousness would have revealed serious difficulties in their identification at any point. These difficulties were manifest to Bishop Berkeley, several centuries ago, when he wrote his essay on A New Theory of Vision and maintained that the primary as well as the secondary qualities of external experience could not be regarded, as required by the physicist's formula, as being independent of the observing individual. If the structures and the changes of physics differ ever so minutely from those which occur in the experience of the observer they cannot be identical with the latter, and must therefore be conceived as comprising a separate though possibly a very similar system of things. It is doubtful whether even with the assistance of the notion of universals, or of platonic ideas, we can legitimately conceive even absolutely similar structures as being numerically identical, if the substances which enter into these structures are different in kind. The fact that our perceptions of spacial, massive, and temporal relationships are conditioned, as was emphasized in Berkeley's classical monograph, upon physiological processes is not in itself proof that these perceptions do not actually include portions of the physical universe. However, the neo-realistic philosophies which explicitly assume this possibility have not as yet succeeded in developing an explanation of the universe which is either simple or plausible.

The acceptance of the principle of relativity settles this dispute within the domain of physical methods alone by admitting that measurements within all three of the fundamental dimensions of physics are conditional for their objective significance upon the conditions of observation. In accordance with the Einsteinian scheme, two observers can make measurements upon what purports to be a single object or system and these measurements may be quite discrepant without either set of evaluations constituting evidence superior to the other; in other words, what any individual observer empirically finds, using the most refined methods of physical analysis and restricting himself to the domain of space, mass and time, is still dependent upon his own standpoint and does not comprise the only true description of external realities. Whether an object is long

or short, or a period of time protracted or brief, depends upon the rate of motion of the observer with respect to the system which contains them, and since there is no criterion of absolute motion, one observer's results are as good as those of any other. The ultimate units of physical science are shown to be purely relative to the conditions of their establishment. Such are the assumptions which are necessary to the simplest and apparently the only plausible solution of the conflicts between the systems of physical data which have developed from astronomical, optical and electro-magnetic observations. In this situation we see the purposes and the facts of physics itself driving the physicist into a repudiation of the last scrap of empirical meaning which it would be possible otherwise by the greatest effort of imagination to read into his system. Thus, in spite of the realism of the naïve and materialistic mind, does psychology at last fall heir to the whole of its natural estate: the totality of immediate experience.

What under these circumstances may we consider to be the estate of physics? Physical formulae, although robbed of their empirical meaning, nevertheless purport to describe a permanent external system of things. How shall we conceive the intrinsic nature of this external system and what exactly are its relations with the system of immediate experience? If space, mass and time, as we ordinarily conceive them, cannot be supposed to exist in this objective physical system, it is still possible that fundamental dimensions of a different character may exist and be such as to resolve the conflict between the results of separate observers formulated in ordinary C. G. S. terminology. Minkowski's symbolic scheme in which time is made a fourth dimension—coordinate with the three dimensions of space—suggests a system of this sort but is not the only alternative nor is it a very intelligible one.

This is the mystery into which modern physics has led us. The problem of the nature of the external universe which physics set out to solve has virtually been abandoned by the physicist, for his present-day description of the universe is couched in terms and in a form to which we can assign no direct empirical meaning. He provides us with the logical skeleton of a system which has no living tissue. What can we do to bring this skeleton to life? In this situation it seems that physics itself can provide us with no further assistance and it is therefore necessary to turn back to the sister science, psychology, whose

domain has expanded within experience as that of physics has perforce contracted. The data of psychology and the facts which relates these data with the physical system, in psychophysiology, may provide us with a clew to the mystery.

II. THE INTERRELATION OF CONSCIOUSNESS AND RESPONSE

When the physicist rejects from the domain of his science a quality of immediate experience, he ordinarily substitutes for it in his system some physical conception expressible in C. G. S. terms. For example, pitch is replaced by a certain frequency of vibration of material particles, while color finds its substitute in very much higher frequencies of electro-magnetic oscillation; hotness and coldness are replaced by certain ranges of kinetic energy of molecular vibration. These surrogate physical conceptions turn out for the psychologist to be the *stimuli* of the respective qualities, when the latter are regarded as sensations. However, these *stimuli* do not operate directly upon consciousness, or immediate experience, but rather upon the physiological organism, taking effect at certain sense organs or receptors which are differentially tuned to respond to various forms of physical activity. Pure introspective psychology is compelled to restrict itself to the analytic description of immediate experience, but psychology in general or at large inevitably becomes involved in a study of the relationships existing between immediate experience and the living organism. This organism is throughout essentially a conception of physical science, it being the creed of mechanism or of antivitalism in biology that all organic structures and processes can ultimately be reduced to physico-chemical constituents. Biology, like chemistry, is in other words, simply a special department of physics dealing with the properties of particular complex physical structures.

We are all familiar with the fact that the modern physicist conceives the ultimate substance of all physical things and processes to be what he pleases to call *electrical*. Electricity, positive and negative, is the fundamental mass-carrying entity of the physical universe, and all actions or interactions are ultimately the expression of electrical, or of the correlated magnetic, forces. If living organisms are simply aggregates of chemical molecules and if such molecules are simply definite congeries of atoms, and if atoms furthermore are nothing but constellations of protons and electrons; then fundamentally organisms are simply vastly intricate structures of these ultimate electrical units and organic functions are wholly reducible to the com-

plex interplay of the electromagnetic forces which are associated with these physical particles. The fact that the intrinsic nature of electricity is not specified by physics, which rests content with its definition in terms of its external dynamic relationships, is merely a further aspect of the general inability of physics to describe its universe in imaginable terms. However, our ignorance of the nature of electrons and protons in and for themselves does not prevent us from ascertaining and describing the structures or processes into which they enter.

The psychologist, as a psychophysiologist, discovers that consciousness is at least in part representable as a *mathematical function* of certain aspects of organic structure and activity. Each individual consciousness appears to be determined by the nature and reactions of a particular corresponding physiological mechanism. There are as many fields of consciousness, or streams of experience, as there exist living organisms, in particular human organisms. It seems to naïve observation and thought as if consciousness were a product of the organic mechanism, as well as if it were capable in turn of influencing that mechanism. This is the doctrine of "interactionism" in psychophysiology. However, the difficulty of conceiving a transfer of energy from the physical organic system to consciousness or the reverse is so great that the majority of psychologists prefer the doctrine of psychophysical parallelism according to which a functional or determinative relationship obtains between the two systems without either being regarded as causally dependent upon the other. That this is an unsatisfactory doctrine may be freely admitted, but upon a level of philosophical argument which (erroneously) regards the psychical and the physical systems as of coordinate reality it cannot be avoided.

The first aspect of the functional relationship between consciousness and physiological factors which becomes available to the psychophysiologist is that which obtains between sense qualities and stimuli. We have noted previously that when the physicist ousted color from the domain of his science he substituted for it, electro-magnetic waves of certain specified length, and since the latter are conceived to be portions of the physical world while the former are now considered as psychological entities merely, this act of the physicist at once establishes a definite psychophysical relationship. From the point of view of the physicist, color and wave-length are simply associated

factors in the external environment of the organism, but the psychophysiologist soon finds that the association is brought about purely through the medium of factors lying within the organism. He finds that electro-magnetic wave-lengths entail the existence of color only if they are acting, or are capable of acting, upon the retina of the eye, and moreover only if the resulting stimulation of the optic receptors is followed by a nerve current set up in the optic fibers and even then only if this current is permitted to flow into the higher nerve centers of the cerebral cortex. A still closer study of the facts shows that the intraorganic factors in this process are apparently more essential than are the stimuli which constitute the physicist's substitute for color. The actual colors which are aroused by given stimuli depend radically upon the condition and the biological type of the stimulated nervous system, and conditions are readily found under which colors appear in the entire absence of a sensory stimulus, and indeed even without the assistance of any current within the optic nerves. What is true of color in these respects holds equally for all other sensory qualities. But this is not all. The same considerations appear to apply also to the primary qualities of space, mass and time in so far as they are given in the immediate experience of any individual. In a word, *immediate experience in its totality is determined by the operations of the nervous system.*

The typical plan of a nervous process is that of what we may call the response arc. Physically considered, neuro-muscular response is merely a special, very intricate, example of the *propagation* of physical disturbances along a restricted *conduction* path. The process consists of a series of stages following each other in space and in time, each depending for its exact character in part upon the nature of its predecessor and in part upon the particular elements in the nervous mechanism which are carrying it. The characteristic successive stages of a response process may be listed as follows: (1) the physical object, (2) the stimulus, (3) the sense organ process, (4) the receptor process, (5) the afferent nerve stimulation, (6) the afferent nerve conduction, (7) the central synaptic process, (8) the efferent nerve conduction, (9) the end plate process, (10) the effector process, (11) the effect. This chain of events, starting with the environment and leading back to it again, is conceived to be physically complete, at no point involving the intervention of any psychical activity.

Now it happens that at the present time there is a slight disagree-

ment among psychologists as to exactly what selection of these various stages of the response process will show the closest correlation with the facts of immediate experience. However, these differences of opinion appear to rest more upon a quest for novel viewpoints, than upon any new data which actually contradict the classical teaching that consciousness in its entirety is correlated directly with the *central* or synaptic process alone; for the simplest explanation of all of the relations which are discovered by the psychophysiologist appears to lie in the idea that the whole of experience, both external and internal, is a function of certain restricted nerve processes occurring probably in one of the association areas of the cerebral cortex. The correlations existing between experience and other stages in the response are, according to this view, indirect in nature, resting upon the purely physiological interdependencies of all of the stages in question.

If we accept this truly astounding principle of the "monophasic cerebro-cortical determination of consciousness" the problem of psychophysiology reduces itself in essence to a study of the laws which relate the component variables of consciousness with those of the cortical mechanism. So far very little which is definite has been established along this line, but the simplest working hypothesis would appear to be that there exists a point-to-point correspondence between the constitution of immediate experience and that of the cortical activity so that for each distinctive characteristic of experience or consciousness there is a corresponding attribute of the brain activity. This is the specific form which the general doctrine of psychophysical parallelism assumes under the influence of the monophasic cerebro-cortical theory. The structures of consciousness, in harmony with this view, would probably depend upon the structural interconnections of various active brain elements; the unity or coherence of consciousness would be correlated with the electrical continuity of the fields of excitation which make up the cortical synergy while the various qualities which form the substance of consciousness would presumably be determined by the varieties of *atomic or molecular* structure to be found in the various cortical synapses.

III. THE METAPHYSICS OF THE PSYCHOPHYSICAL RELATION

Having considered the outcome of sophisticated reasoning in the domains of physics and of psychology, let us return once more to the point of view of the primitive intelligence with which we began. Let each one of us, for the moment, identify himself with this in-

telligence. I will speak in the second person to enforce the realism of the argument which is to follow. At the start you, the naïve thinker, divided your total experience into internal and external sections, assigning the study of the former to psychology and of the latter to physics. At first you regarded the whole of your external experience as forming part of a world which existed independently of your experience, but as you progressed in your physical thinking you found that more and more factors in your external experience failed to measure up to the demands of this belief and hence had to be rejected from the subject matter of your physical science. Eventually you retained only space, mass, and time, substituting complications of these for all other empirical factors, but then Einstein appeared upon the scene and proved to you that these also could not be conceived to exist unmodified apart from your own experience. You then found yourself in the predicament of having built up a highly specific and intricate logical system, to the component terms of which you could no longer attach any imaginable meaning. This logical system, written in symbols in your books, still purported to refer to a real external universe, but what that universe could be like in itself was a question which you now found yourself quite unable to answer. To say that its ultimate substance is electricity would merely be to confess implicitly that, although you knew something *about* it, you knew nothing at all *of* it.

In this situation you seem about to admit your complete ignorance of the nature of *any* reality apart from your own immediate experience. But if you will ponder a moment you will find already resident in your thought a very potent belief in the existence of certain realities apart from your experience, but realities which are, in general, quite different from any part of the physical world. The realities in question are the consciousnesses, or experiences, of *other men*. These you suppose to be similar in character to your own consciousness but nevertheless to be quite separable from the latter and to be entirely independent of it for their continued existence. In order again to lend realism to the argument I will take as an example of other consciousness my own experience contrasted with yours. Suppose now that, having become interested in consciousness, you become a psychophysiologist and work out the relationship which must be conceived to exist between my consciousness, or experience, and your symbolic physical world. You will find, as we have seen, that my

consciousness is correlated point for point with certain physical structures and processes occurring within a very restricted portion of your physical system which you call my *brain process*. This physical brain process of course you cannot for a moment conceive to exist apart from your own consciousness and even here it will ordinarily have only symbolic or logical existence; you think, talk and write about it a great deal but, except in the rare instances where you happen to be a brain surgeon and I happen unfortunately to be your patient, you never come anywhere near seeing it. But even if you were actually to perceive my brain process in all of its molecular detail you would not dare to affirm its external reality any more as a system of C. G. S. quantities than as an arrangement of color surfaces in space. Yet you do believe firmly that your conception of the structures and processes of my brain does, like the remainder of your conceived physical universe, correspond with *some* reality external to your experience the logical constitution of which is closely similar to that of your physical scheme.

Under these circumstances can you not most assuredly be convicted of intellectual incapacity if you do not recognize in *my consciousness itself* a perfectly good reality which may constitute the actual meaning of your physical symbol called a brain process? In your ultimate philosophy of physical science you affirm that all of your physical equations stand in point to point correspondence with an unknown reality. In your interpretation of the data of psychophysiology you affirm in the doctrine of the parallelism between consciousness and the brain process that my individual experience stands in exactly this relation to a certain part of your physical system. Why, then, should you not admit that my experience *is* the reality towards which this particular section of your physical system has always been pointing?

This is a doctrine which is easily heard but which is very difficult to see. It *rhymes* with the evidence, but yet it seems to conflict too much with common sense; with common sense physics and with common sense psychology. We have too long considered mind and matter to be two irreconcilably disparate but nevertheless interacting entities; matter a substance and mind an intangible activity. Now we are required to treat mind as if it were a substance and to identify it with the reality of matter. The doctrine is apt to cause much confusion in our thoughts because it turns all of our old mental furniture

topsy turvy. Nevertheless, if it is accepted and its implications followed it will be found to clarify and to simplify our entire conception of the universe. It can solve, firstly certain profound mysteries into which we are led by modern physics, the mystery of electricity, the riddle of relativity, and—I am inclined to believe—the enigma of the quantum theory; secondly, it will obliterate the dualism of mind and matter by actually explaining the relation of psychophysical parallelism upon a monistic basis; and thirdly it will provide us with an organon for the systematic and rational study of the real universe which lies beyond our own individual experiences.

A theory possessing powers such as we have just alleged should be expected, once it was clearly formulated, to take the philosophical world by storm. Sad to relate, this expectation seems doomed to disappointment. The father of psychophysics, G. T. Fechner, stated the doctrine in principle in 1863. W. K. Clifford rediscovered it in 1878. Alfred Barrat evolved practically the same doctrine in 1883 but his book seems quite unknown to any other writers on the subject. Independently in 1885 it was evolved by Dr. Morton Prince. But in 1903 and 1905 it was elaborately expounded practically without reference to previous expositions, by C. A. Strong and G. Heymans, respectively. Only two English speaking psychologists, Stout and McDougall, have taken any cognizance of the doctrine, although it eliminates difficulties concerning the discussion of which psychologists have wasted thousands of pages of manuscript. I worked out the theory myself in great elaboration, probably from suggestions contained in Paulsen's Introduction to Philosophy in my undergraduate days. Heymans' book, which appeals to me as being the keenest discussion of metaphysical problems which I have ever read, appears to be entirely unknown in the department of philosophy at Harvard and at no time during my own study in that department do I remember having heard the theory of psychical monism mentioned even casually.

The failure of the doctrine to take root in the minds of philosophers and psychologists is due I believe to their habitually fuzzy methods of thinking. It is a doctrine much better adapted in form to the mathematical mind of the physical scientist. But although the form will suit the physicist the substance unfortunately probably will not do this. Here, again, it may fall upon barren soil, but I am trying the experiment of sowing it there now.

IV. THE PSYCHICAL MONIST'S UNIVERSE

In order to show how our hypothesis may possibly accomplish some of the great things claimed for it, we must elaborate its implications in further detail. Let us adhere to the use of the second and first persons as before to make vivid the situations which are involved.

You must begin your thought with the assumption that the reality lying behind your idea or perception of my cerebral process is simply my total introspective consciousness. The various material or dynamic components which you perceive or conceive within this brain mechanism are merely the individual representations within your own consciousness of these components of my consciousness. Each element in your picture of my brain process is in reality simply an element of your own consciousness, but it may be considered as an *effect or product*, however remote, of the action of a corresponding, but ordinarily quite different, element in my consciousness. The structure of the brain process is but the reflection in a psychophysical mirror of the structure of consciousness; although it is a product not so much of optical as of philosophical reflection.

It should be clear to you at once that this hypothesis quite resolves the dualism of mind and matter and provides a real explanation of the psychophysical relation. It destroys the dualism by dethroning matter from its exalted seat as a peer among substances with mind. Matter, or electricity, is denied existence except in so far as it is actually presented within any given concrete field of experience, but within such a field it cannot be the matter concerning which physics speaks and can only constitute psychological matter or specific perceptual complexes of sensory qualities. Hence in so far as our doctrine of psychic monism admits the existence of matter, it classes it as a subdivision of consciousness. The physical systems which we are considering in our discussion of the brain process, however, do not even have this degree of reality, since all that is presented in consciousness at the moment of discussion are complexes of visual or auditory sensations or images which are commonly called words. These words, it is true, are supposed to have meanings, but the meanings are by hypothesis not regarded as being within consciousness, and hence we are quite at liberty—so far as the evidence of immediate experience is concerned—to deny their existence altogether.

When we see thus clearly what is actual and what is possibly only fictitious in the psychophysical relationship we recognize that this

relationship as ordinarily conceived holds between any individual consciousness and the non-existent meaning of a physical scientific description. The only parallelism of reality is between the conscious system and the descriptive system, but the descriptive system employs, in general, terms which are not suitable to the nature of consciousness. The psychical monist suggests that this is an error, the description having actually been determined in its logical form by unrecognized influences emanating actually from the given consciousness, so that the tangled threads may be straightened out simply by substituting in the description, terms and elementary relations which are appropriate to psychical manifolds in general. The explanation of psychophysical parallelism which is afforded by psychical monism is therefore analogous to one which would show why the shadow of a man should follow him about and be roughly similar to him in contour and gesture. Both the shadow and the man are integral parts of a homogeneous system, but they happen to enter into a peculiar relationship—not at all characteristic of the structure of the universe as a whole—in which there is an apparent parallelism of parts and of activities. The psychical monist's explanation of the functional relationship which psychophysiology finds to hold between consciousness and the brain process is every whit as good as is the physicist's explanation, within the domain of optics, of the relationship which obtains between object points and image points in reflecting or refracting systems. The exact physical counterpart of the explanation, however, is to be found in the relation existing between the object and the brain process in the mechanism of response; for the exact physical picture of what is happening when my consciousness is acting upon yours is given by my brain process becoming the object in the response propagation which culminates in your brain process.

The psychical monist, however, has not finished when he has dissipated the mystery of psychophysical dualism. He must go on to consider the larger psychical universe which lies beyond your particular consciousness or mine. Since the facts of psychophysiology indicate that my introspective consciousness correlates with only a small portion of what you perceive or conceive as my physiological organism, the question obviously arises as to what significance can be assigned, in the universe external to your consciousness, to the *remainder* of my organic structure and processes as conceived by you. In the first place, you may consider the fact that not my total nervous

system nor even the whole of my cerebral activities are apparently associated with the immediate production of my introspective consciousness, but only a restricted area of the cerebral processes. How shall you interpret the immediately outlying cortical activities? I might answer that these are probably the results of your attempt to conceive physically a reality which I call my *subconscious mind*. Some psychologists have experienced a great deal of difficulty in conceiving the subconscious mind actually to be conscious. But from the point of view of psychical monism this is a very easy thing to do. Consciousness is treated as a qualitatively differentiated substance which is capable of forming systems of greater or less complexity and of varying degrees of coherence. Just as your consciousness and mine are both conscious yet not mutually inclusive nor even, it would seem, connected in any conscious way, so my introspective field of awareness and various depths of the subconscious may all be conscious without being co-conscious or uniting to form one integral coherent system.

If you follow this line of thought with regard to what may be called the psychical environs of my introspective consciousness you will be led to believe that my consciousness is psychically surrounded by a system of psychical entities or processes bearing the same relationship to it that the brain processes which envelop the central cortical activities bear to the latter. For every neurone in the nervous system and for every atom in each neurone there must be a real psychical fact which is related to my consciousness just as my neurones and their atoms are related to my central brain process. My field of introspective consciousness must, in other words, be considered the focus of a vast psychical nervous system, a nervous system made not of protons and electrons but of atoms of sentiency. Within this system there transpire propagations of influence converging upon and diverging from my introspective field which correspond exactly with the neuro-muscular response processes which you picture to yourself when you are thinking of the operations of my nervous system physically. Your physical conception of this response is indeed clearly nothing but a symbolic representation of the real psychical response system, which is of a sort which was functioning in connection with the consciousness of primitive man before any of the conceptions of modern physiology were even dreamt of.

You cannot stop here, however, you must go on to consider the

meaning of the non-nervous portion of my organism as you conceive it, and, furthermore, the significance of the world of physical stimuli and objects which surround it. The intra-organic stages of response are merely certain links in a continuous chain of influences which flow into the organism at the sense organs and out of it at the effectors, and the nervous mechanisms of the organism differ only quantitatively from those of other tissues. The continuity of physical nature commands that you expand your conception of the psychical universe into a structure which corresponds point for point not only with the parts of my nervous system but with all the constituents of my organism and of my environment; indeed, with the totality of the physical universe as conceived by the most comprehensive physical mind. You are thus led to the conception of a complete universe of objective consciousness, the formal structure of which is substantially identical with that described by the physical sciences of biology, geology and astronomy, but the substance of which is similar to what the psychologist finds in immediate experience. The processes of this great psychical world, being—like those of the physical system—mainly a succession of different structures, must also be formally identical with those which the physical scientist describes. This inference from the general homogeneity and continuity of the physical system which embraces my brain mechanism, therefore leads you to a rational and meaningful interpretation of your entire physical hypothesis. It is this psychical universe at large, in which my consciousness and also your own are small but integral parts, which constitutes the real objective meaning of the relativity C. G. S. electro-magnetic schema in general physics.

Certain apparent difficulties which arise in connection with this doctrine can readily be shown to be specious. In the first place there is the difficulty of conceiving consciousness or the psychical as a self-existent substance which is capable of forming definite structures. This difficulty arises from an adherence to the idea of consciousness as a relation between a self or ego and an object, whereas modern introspective psychology quite rejects this conception, along with that of the ego, and identifies consciousness with the mosaic of sensory and other qualities which were regarded as contents or objects of consciousness in the older, relational theory. Consciousness, for the modern psychologist, is essentially a mosaic which must be analyzed into elementary qualities and their interrelations, so that pure intro-

spective psychology is often designated as structural psychology. That the qualities and the structural coherences of consciousness are capable of existing in their own right is certainly a reasonable supposition, since the very idea of existence must inevitably rest upon the demonstrable reality of these data of experience. Another similarly specious difficulty appears in the persuasion that the panpsychic extension of consciousness to correspond not only with brain processes but with all material systems makes the universe unduly complex; so that the doctrine seems liable to succumb to the onslaughts of Occam's razor. This objection is specious because psychical monism, unlike dualistic panpsychisms, does not *add* consciousness to the equation of matter but substitutes it within this equation. The resulting system is therefore of exactly the same degree of complexity as that of physical science and the latter has vanished from the metaphysical arena completely, appearing now merely as stage of reasoning—like those of pure mathematics within physics alone—leading up to the final account of things. The psychical monist's system is, as a matter of fact, much simpler than any materialistic scheme which acknowledges all of the data of experience, for all such schemes inevitably demand dualism and reduplication of factors wherever the existence of consciousness can be demonstrated. For psychical monism, on the other hand, all demonstrable fields of consciousness are merely interlocking parts of a system which in its totality is no more intricate than a materialistic system which excludes all considerations of consciousness.

In reality, the complete psychical system is probably even simpler than this. The physicist thinks of each component electron or proton in his system as retaining its discreteness or individuality regardless of the relations of combination into which it enters with others. Synthesis, for the physicist, is not of the elements themselves but only of the structures, which are condensed in space and increased in stability. There is convincing evidence, however, that atoms of mind-stuff do not behave in this way, and that when they combine they actually fuse—in varying degrees according to circumstances and partially—or, in the limit, wholly—lose their identity. Such fusion results in the generation of a new over-all "form quality" of the resulting integral which is the conservation index of or compensation for the sacrificed discreteness of the combined elements. This is real synthesis, and while it increases the qualitative diversity of the

components of the universe, it greatly simplifies its structure. The necessity for a principle of this sort operating in the psychical universe first appears in a consideration of the relations between so-called elementary components of experience—such as any point sensation of color—and the corresponding brain components. Although the former seem simple the latter must almost certainly be complex. There are only two kinds of ultimate physical elements, positive and negative electricity, while there are thousands and probably millions of qualitatively distinct, irreducible, elements of consciousness. Clearly these psychic units cannot correspond to protons and electrons or even to specific chemical elements, but must be correlated with molecular, colloidal, or crystal species.

Here the parallelism of structure between the physical and the psychical systems appears to break down; only in the grosser and more disperse organizations of matter can it be conceived to hold at all rigidly. Possibly there is some slight degree of structure in so-called elementary qualities, but not enough to arouse an analytic judgment. At any rate we may suppose that when such qualities decompose, as in the analysis of a musical chord or clang, they always yield definite end products in a definite structural relation, so that they may always be said to have potential structure. Physics derives its physical diagrams of the constitution of these finer parts of its universe almost entirely from a study of the ways in which they can be formed or the manner in which they break down, and hence may be accused of reading into them an exaggerated structurality. In terms of given existence rather than of history or prophecy, however, the translation of physical space structures into psychical realities will involve the transmutation of an increasing fraction of structurality into specific quality, as the physical mosaics become more cohesive and in general more microscopic.

These considerations indicate that although the technique of physical thinking—according to our interpretation—is implicitly aimed at a determination of the abstract structure of the psychical universe, this technique is not as yet perfectly adapted to that purpose. In regard to structure, it overshoots the mark. In other ways, it may introduce into the physical scheme of concepts, artifactual terms and relationships, which have the same irrelevancy to the real universe which the surds and irrational numbers of mathematical technique have to the physical scheme by itself. Considerations of this sort

may throw light upon certain mysteries of modern physics, such as the quantum theory of energy transfer. This conception of atoms of activity which seems absolutely essential to the explanation of known laws of the emission and absorption of radiant energy appears to be squarely in conflict with phenomena of the interference type upon which the continuous wave hypothesis was founded.[1] Is it not possible that this quantum conception—like the irrationality of π—is attributable to an artificial incommensurability of the present concepts of physics and the properties of the real universe? An inkling as to the nature of this incommensurability is given by our considerations regarding the reality of psychical synthesis. If the physicist overestimates the discreteness of the various parts of the universe, he may find it necessary to compensate for this by overestimating the discreteness of the changes which occur within or between them. His changes are fundamentally expressed as ratios of spaces to times and an erroneous factor in the structural numerator of this ratio could therefore be canceled in its influence upon conclusions by an equivalent, erroneous factor in the temporal denominator. We might explain the introduction of this latter factor by the hypothesis that the local time of any single radiator is atomic or possessed of a cell structure so that successively emitted quanta, although distributed at random within these cells would be held in constant phase from the point of view of a receiver, by always beginning at the front end of a given time cell, and on the average filling large blocks of such cells homogeneously. But this would merely be another outrage to our common sense ideas and a further indication of the unreality of the physicist's schema.

It is along similar lines that the psychical monist rationalizes the principle of relativity. This principle immolates the stability of empty space and time to the constancy of the velocity of light under all conditions. But the psychical monist sees at once that empty space and empty time have no objective meaning whatsoever. In the psychical universe, space has significance only for the form of combination of concrete psychical units. Where such concrete units are absent there can be no form of combination and hence only non-

[1] This paragraph was written from the point of view of J. J. Thomson's "pulse theory" which renders understandable the mechanism of emission and absorption of quanta. The more current idea of a quantum as a short train of continuous waves fits in better with interference phenomena, but in doing so simply places the paradox in a different place, in the processes of emission and absorption.

existence. The same is true of time, which is merely an aspect of concrete changes and their functional interrelations. Such interrelations are symbolized physically by the transfer of radiation, and the velocity of this transfer is thus the natural reference constant for the establishment of standard temporal and structural systems. Although we may not be able from these considerations immediately to deduce the Einsteinian equations, we can at least recognize that the psychical monist's universe is sufficiently different from that of non-relativity C. G. S. physics to make it possible for the equations in question to fit its properties without inconsistency.

In conclusion a word must be said concerning the relation of the psychical monistic hypothesis to the philosophical discipline known as metaphysics. This discipline has several subdivisions, such as epistemology and ontology, but one of its main efforts has always been to determine the inherent nature of reality, and in particular reality independent of individual experience or merely "phenomenal" representations. For every phenomenon it has tended to postulate a "noumenon" or a thing-in-itself. Physics, as I have interpreted it, clearly has a strong metaphysical inclination in this respect, but only materialistic metaphysics has accepted physics as actually answering the metaphysical, or the "metempirical" question. Metaphysicians other than the materialistic ones have in general worked entirely by arm-chair guesses or have employed idiosyncratic methods, such as Hegel's principle of thesis, antithesis, and synthesis. Now, psychical monism very evidently steps into the metaphysical arena with a definite theory of the general nature of things in themselves; but it does more than this, it brings with it a sword with which to engage in the metaphysical fray of words: a definite method of research.

This new method or "novum organon" for metaphysics consists simply in determining carefully the laws which link the factors of human consciousness with those of brain function and then generalizing these laws so that they can be applied not merely to brains but to any physical structure or process whatsoever. The possibility of doing this rests upon the continuity of nature and upon the belief that human consciousness is sufficiently complex to exemplify all of the elementary psycho-physical relationships. It is the principle of the "flower in the crannied wall" from a careful study of which we can infer the constitution of the entire universe.

If time permitted we might go on to apply this method at least

in a preliminary way to see to what specific depictions of the general psychical universe it may lead us. However, I can here only express my belief—justified by theoretical results already achieved—that the doctrine of psychical monism will not only throw light upon the mysteries of physics and of metaphysics but also upon those of religion and of ethics. When we know exactly what manner of universe we live in we shall know whither that universe is going and what our own part must be in its evolution.

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PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

WASHINGTON ACADEMY OF SCIENCES

161ST MEETING

The 161st meeting of the Academy was held jointly with the Botanical Society of Washington at the Cosmos Club, the evening of Thursday, December 15, 1921. Dr. WILLIAM E. SAFFORD, of the Bureau of Plant Industry, U. S. Department of Agriculture, delivered an illustrated address upon *The food plants of Ancient America.*

Every food staple encountered by the early explorers and colonists of America was new to them. Not a single Old World cereal, vegetable, fruit or root-crop, had found its way to this continent before the discovery. American agriculture, as practiced in various regions both north and south of the equator, was endemic. The cultivated food staples had been won by the Indians from wild shrubs and herbs: maize from a wild grass; squashes and pumpkins from wild gourds; common beans and lima beans from leguminous vines scrambling in thickets; potatoes from a tuberous weed of the Andes; sweet potatoes from one of the many wild morning-glories; peanuts (*Arachis hypogea*) from a wild vine that ripened its seeds under ground; tomatoes and capsicum peppers from solanaceous plants of the hill-sides and plains; pineapples from coarse prickly-leaved plants of certain semi-arid regions of Central America; chocolate from the seeds of a tropical American shrub; and tobacco from several species of clammy ill-smelling weeds allied to the narcotic henbane of the Old World.

The very early dissemination of some of these plants led to conflicting theories as to their origin. A recent writer, unhampered by botanical knowledge, declares that tobacco and several other well known American economic plants were brought to America from the Old World. He stigmatizes Columbus and his companions as liars, and modern ethnologists as fools. Even botanists have advanced erroneous theories regarding the origin of well-known food plants, one of the authorities on the gourd family, for instance, declaring the squashes and pumpkins of America to be of Asiatic origin. De Candolle himself was governed too much by acounts of early travellers, which were often vague and unsatisfactory. Owing to such accounts, the South American potato (*Solanum tuberosum*) has been confused with the openauk, or ground-nut, of the Virginia Indians (*Glycine apios*), which the early French colonists called "racine á chanelet;" and the peanut (*Arachis hypogea*) has been confused with the North American ground bean (*Falcata comosa*) and the African *Voandzeia subterranea*, both of which have subterranean fruits. Other examples are the confusion of the American *Cucurbita maxima* and *C. pepo* with Old World gourds. Fortunately we have an abundance of material from prehistoric graves, including remarkably well preserved fruits, seeds, and tubers of food plants, as well as beautiful reproductions of the same in the form of funeral vases of terracotta.

Among the food products shown on the screen were specimens of maize from ancient graves and burial mounds of South and North America; seeds, shells, and stems of squashes and pumpkins, and beautiful reproductions of *Cucurbita pepo* and *C. maxima* in terracotta; many distinct varieties of *Phaseolus vulgaris and P. lunatus;* actual specimens of *Arachis hypogea* in a remarkably perfect state of preservation, and terracotta vases incrusted with peanuts modeled from the fruits themselves; specimens and models of potatoes (*Solanum tuberosum*), sweet potatoes (*Ipomoea batatas*), mandioca (*Manihot utilissima*), and dichotomous roots of *Canna edulis*. Some of the models were in the form of idols, one of the squashes having the figure of a god mounted upon it, and a canna root having also a human head depicted on the principal root. A corn god surrounded by ears of maize was in the form of a monster with great tusks protuding from the mouth; a terracotta figure, evidently the god of agriculture, held in one hand a stalk of maize bearing ears and tassel and in the other a stalk of mandioca bearing a fascicle of fusiform roots. Many of the specimens shown were from collections made by the lecturer while exploring in South America.

Lantern slides of wild fruits, tubers, and edible roots were also exhibited including the principal species used by the Virginia and New England Indians, and wild grapes from which the Concord, Catawba, Niagara, and other well-known varieties of cultivated grapes have been developed in modern times.

WILLIAM R. MAXON, *Recording Secretary.*

ENTOMOLOGICAL SOCIETY

337 MEETING

The 337th regular meeting was held on February 3, 1921 in Room 43 of the new building of the National Museum, with President WALTON in the chair and 32 members and 6 visitors present. The following were elected to membership in the society; E. H. BLACKMORE of Victoria, B. C. ; R. J. TILYARD of New Zealand; B. A. PORTER of the Bureau of Entomology; and MELVILLE H. HATCH of Ann Arbor, Michigan.

Program

R. C. SHANNON: *Notes on the classification of the Syrphidae.*

This classification is based on external characters of the adults. Ten subfamilies are recognized and practically all the characters used to define them are here used for the first time. The most notable feature in the paper is the definite separation of the *Syrphinae*, containing the aphidophagus forms, from the other subfamilies.

Dr. J. M. ALDRICH expressed himself as much gratified with Mr. SHANNON'S work on the *Syrphidae*. He stated that previous classifications of the family have been based on what might be called traditional characters which give an unnatural grouping of the genera.

L. O. HOWARD: *Extracts from Ferton's review of Fabre's work.*

Doctor HOWARD stated that he had recently carefully translated two articles from the French relating to J. H. FABRE. The first, which was an enthusiastic eulogy, was published by BOUVIER in the *Revue generale des Sciences pure et appliquees*, 26e Anneé, **22:** 634–639. Paris: 30 Nov., 1915; and the second was a critical estimate of the character and work of FABRE by CH. FERTON published in *Revue Scientifique*, 16–23, September. 1916—leading article. Doctor HOWARD read abstracts from the latter article in order to show the members of the society the true estimate of FABRE that is held among the best scientific men of France, especially those best fitted by their work to appreciate at their true worth the reported observations of the Hermit Naturalist.

The translations will be bound and placed in the library of the Bureau of Entomology at the end of the series of the published works of FABRE.

Mr. S. A. ROHWER expressed the opinion that from the point of actual observations FABRE'S work does not equal that of the PECKHAMS or the RAUS. He questioned if the good that FABRE did as a popularizer of entomology would outweigh the harm that he did to the science by his bitter antagonism to the evolutionary theory. The erroneous determinations of species made by FABRE have made his work much less valuable than it would have been had he secured correct determinations from competent authorities. Mr. ROHWER stated that the same criticism applies to some extent to some American works on the habits of wasps, notably that of HARTMAN in Texas.

Mr. SNODGRASS was inclined to overlook the inaccuracies of FABRE'S work stating that in American entomological literature there are many errors as bad as those of FABRE'S. He cited as an example the statement that the tussock moth removed the hairs from its back by means of its mandibles and weaves them into its cocoon. He had observed the method by which these hairs are removed and found it to be accomplished by a revolving motion of the larva in its cocoon, by which the hairs are rubbed off and becoming tangled in the silk of cocoon form a part of the cocoon.

E. D. BALL: *Food plants and adaptations of leaf hoppers.*

Treehoppers exhibit many lines of adaptation to their surroundings. They have been chiefly famous in the past for their remarkable and bizarre shapes. These curious and intricate modifications are all the result of an extraordinary enlargement of the chitonous covering of the pronotum. These horns, spines, balls, warts, or foliaceous prolongations may be clipped off as one trims the finger nails without in any way injuring the insect whose body is of normal shape and proportion down at the base of this hood. One South American species at least appears to be able to shed without difficulty a foliaceous bulb that covers its back. This is probably a protection against insec-

tivorous birds. Most of the other strange developments seem to be protected by simulating some part of the plant on which they live or else so arranged as to blend into the lights and shadows of their favorite situation as to render them inconspicuous. For example, a species that lives on the oak has a white stripe down the middle of the back which is very striking when seen in a collection. This insect, however, in life rests on the underside of a twig in the shadows and this white stripe then functions like the light under part of the deer or of many birds and helps it to blend with its surroundings.

The adaptation of these insects to their surroundings in color and markings is if anything even more striking than their grotesque shapes. A study of the North American species of *Telamonini* shows that nearly every one of them has a single food plant to which it is almost perfectly adapted in color and form, these adaptations being combined to produce invisibility in the favorite situation of the individual treehopper. The one occurring on wild plum, for example, has the color of the plum bark and a long projection like a plum thorn. The one on sycamore has the powdery yellow appearance of the fresh bark of that tree. The one on hackberry rests in crevices in the bark and mimics the rough outline of the black and gray flecking of the rough bark.

Collecting these insects is as fascinating as trout fishing. It is only the trained eye that can detect them and when detected it is only by the use of the greatest skill that they can be captured, as once disturbed they snap into the air with eye-defying speed and are lost in the foliage. If one uses a long glass tube and brings it down from directly above the insect without allowing the slightest lateral movement they may be readily captured. They are lovers of the open and of warm and sunshiny places and will be found on isolated trees or small clumps or on the margins of woods but not inside the wooded area or in the deep shade. Fortunately for the collector most of them occur on the low spreading branches of the large trees.

Notes and exhibition of specimens

Mr. B. A. PORTER reported the rearing at Wallingford, Connecticut, of *Anaphoidea conotracheli* Girault, a common parasite of the plum curculio, from the eggs of the apple maggot. As high as 25 and 30 per cent of the apple maggot eggs collected in the field have been found to be parasitized by this insect. The egg turns dark just before the emergence of the parasite, which instead of using the oviposition puncture made in the fruit by the fly makes a hole of its own through the skin of the apple. The life cycle of the parasite was not definitely determined but data available show it to be less than three weeks. In the plum curculio it is 10–11 days. The oviposition season of the apple maggot following that of the plum curculio gives a favorable host rotation from June to September. The only other recorded host of this parasite is the grape curculio.

Dr. HOWARD was much interested in the observation and expressed the opinion that any delicate egg deposited in the same position as those of the curculio and the maggot would serve as host for the *Anaphoidea*.

Mr. GAHAN mentioned *Trichogramma minuta* Riley as another example of a parasite attacking eggs of insects of different orders.

Dr. J. M. ALDRICH, editor of the THOMAS SAY Foundation, stated that the Foundation would shortly be able to publish another memoir and asked for the opportunity to examine any manuscripts that might be available.

R. A. CUSHMAN, *Recording Secretary.*